Offshore Flow and Internal Boundary Layers

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LONG-TERM GOAL

Our main goal is to separate the influences of stability, wave state, and internal boundary-layer development on air-sea surface exchange. This requires re-examination of the basic structures of internal boundary layers in offshore flow and the physics of their development.

OBJECTIVES

Our objective is to replace the present concept of the internal boundary layer with a more complete picture and eliminate the basic idealizations in the "textbook" internal boundary layer. We will then modify the standard bulk aerodynamic formulations to include the effects of internal boundary layers and wave state.

APPROACH

We are analyzing an expanded data set collected during the Risoe Air Sea Experiment. This field program includes a heavily instrumented tower 2 km off the Danish coast which provides detailed profiles of fluxes, wind, and temperature. We are also analyzing an early data set collected by a series of towers on a beach of a Frisian Island off the coast of The Netherlands. This data set, which has not been previously analyzed in any detail, interogates a heated internal boundary layer as cool air flows from the oceanic surface over the warm beach. We will also assess the utility of several other data sets.

WORK COMPLETED

Only one graduate student, Cheryl Klipp, has been hired to date and she has concentrated on analyzing data in the Dudamex experiment where the development of internal boundary layers over the beach in onshore flow was measured using a line of towers. John Holeman was hired in July of 1999 and is modifying an LES model to study offshore flow.

RESULTS

The DUDAMEX (The Dutch-Danish Meteorological Experiment) was conducted in June 1979 on Schiermonnikoog Island in the Netherlands using a series of towers. This is the only data set known to us which examines the detailed structure of the growing internal boundary layer in onshore flow in the first hundred meters over land. It is also unique in that 3-D sonic anemometers were placed not just vertically but also horizontally on the beach. We have focussed on a case study where cool marine air was blowing over a sun-heated beach at about 3.5 m/s.

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Typically, internal boundary layer theories assume a sharp, relatively smooth interface between these two regimes where the interface has a thickness on the order of diffusion scales and minor fluctuations in height. In examining the 20 Hz data at all seven sites, we can see that although there is evidence that the interface between old and new boundary layers is fairly sharp, its height fluctuates rapidly. The 2 meter observations at 40 meters from the shore the 5-meter observations at 80 meters from the shore were inside the new boundary layer during some periods and above the interface during other periods. The new internal boundary layer occasionally reached the 10- and 20-meter heights as well.

This implies that despite a sharp instantaneous transition between old and new boundary layers, the thickness of the zone in which the interface undulates is comparable to the height of the interface (Figure 1). The time-averaged interface between the new land internal boundary layer and the old marine boundary layer is vertically thick without a sharp transition.

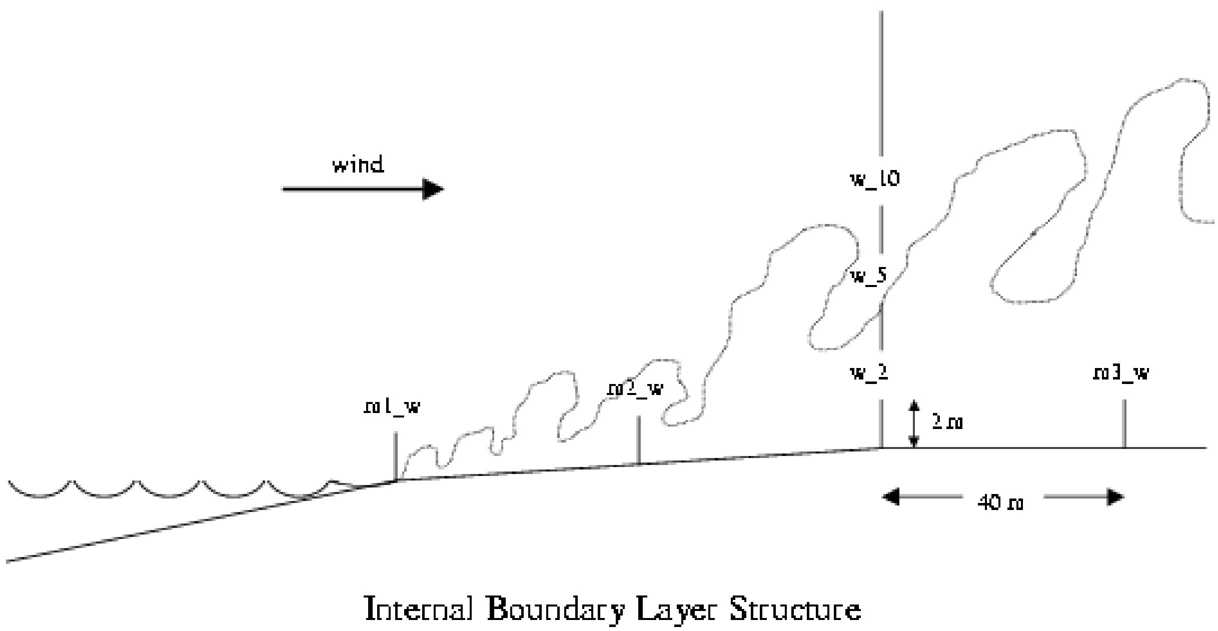

Figure 1. A qualitative sketch of the interface in a weak wind situation surmised from the observed intermittency of the fine scale turbulence.

In most studies, the top of the internal boundary layer is found by using averaged data. From the vertical profile of the 1-hour standard deviation of w, the internal boundary layer depth would seem to be 10 meters above the ground at the tower location of 80 meters from the water line. In terms of fine scale structure (1-sec. standard deviation of w), the internal boundary layer depth is closer to 5 meters at the 80-meter site. This study indicates that the development of the convective internal boundary layer is more complex than previous studies have indicated, and this complexity is quite important close to the shore where the depth of the interfacial depth is not small compared to the height of the top of the internal boundary layer.

The LES modeling of offshore flow has been limited to model modification with no significant physical results or comparison with data, to date.

IMPACT/APPLICATION

Even under near-perfect conditions, the classical concept of an internal boundary layer requires modification, and coastal zone meteorology must be generalized accordingly. Dispersion and vertical structure in the few hundred meters in onshore flow over the land is probably poorly modeled since such models assume a sharp interface for the time-averaged flow.

RELATED PROJECTS

Analysis of offshore tower eddy correlation data is being carried out under grant N00014980282 from the Office of Naval Research. This data set allows analysis of detailed vertical structure in the lowest 40 m whereas the above work concentrates on horizontal structure in the coastal zone.

Under the ONR grant entitled "Spatial Variations of the Wave, Stress and Wind Fields in the Shoaling Zone" (N000149710279) conducted a field program at Duck, North Carolina in March of 1999. This program concentrated on spatial variations in the coastal zone with offshore flow of warm air over cool water using the LongEZ aircraft. The fall program will concentrate on interaction with atmospheric turbulence with the surface wave field.

PUBLICATIONS

None